WATER RESOURCES MANAGEMENT IN AGRICULTURE: CONVERGENCE OF NEEDS AND OPPORTUNITIES

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Abstract

Three issues of global interest and concern are water scarcity, food insecurity and HIV/AIDS. The first two issues are addressed in this paper. The water crisis is mostly due to lack of sustainable utilization and management of water. With the ever increasing human population, rural-urban migration, environmental degradation, rapid deterioration of freshwater quality, loss of fertile lands and ecosystem resilience, there is need for enhanced management of productive water in agriculture. This is the only way of averting the grave social consequences that will follow the inevitable water re-allocation to urban, industrial and mining sectors that make greater contribution to the GDPs of most countries.

Research in Agro-hydrology, discussed herein, provides vast opportunities in bringing about the "more crop per drop" revolution. Agro-hydrology provides a meeting point of agriculture and hydrology in a broader sense of IWRM with land and soil fertility management for enhanced crop water productivity from the farmer's plot to the basin scale.

Keywords: *Water Resources Management, Agrohydrology.*

1 Global Perspective

On the global arena, water scarcity, food insecurity, and HIV/AIDS pose the gravest threat to human existence. The ubiquitous phrase "water is life" underscores the importance of water not only for the sustenance of all living organisms, but as an engine for growth and development of human societies. At the United Nations conference on Environment and Development, generally referred to as *The Earth Summit*, held in Rio de Janeiro in June of 1992, it was obvious to world leaders that a water crisis was already evolving with portending ominous and grave consequences. The adoption of Agenda 21 by world leaders at that conference provided the blue print for sustainable management and development for various natural resources of which freshwater was one. (Chapter 18 of Agenda 21 titled, *"Protection of the Quality and Supply of Freshwater Resources."*) Prior to, and as part of preparations to the Earth Summit in Rio de Janeiro, an international conference on Water and the Environment was conveyed in Dublin, Ireland in January 1992 to specifically address issues related to the use and management of water. One significant outcome of that conference is what is now commonly referred to as the "Dublin principles" which provide the guiding principles for planning, development, and management of water-related projects and continue to form the basis for all subsequent global discussions in the water sector. While it is recognised that there is disproportionate distribution of water on the earth surface in relation to critical water demand centres, the crisis is not due to actual quantities of available water but to the wasteful and unsustainable manner that water is being used and managed in many parts of the world. In addition to adopting the Dublin principles at the Earth Summit, leaders strongly encouraged all governments to promote integrated water resources management (IWRM) as a unifying strategy in implementing the Dublin principles. IWRM, as a process, promotes a coordinated approach to the development and management of national and regional water, land and related resources so as to achieve equitable access to, and sustainable use of these resources by all stakeholders, while at the same time maintaining the integrity of these resources for use by future generations (GWP, 2000). It remains a daunting challenge how this strategy can be implemented in many nations and regions of the world. "The challenge is not just to set up multi-components programmes, but to make the components work together coherently so that the whole is greater than the sum of the parts." (DFID, 1998) While the Dublin principles advocate the decentralization and management of water projects to the lowest appropriate level at which participatory methods can be utilised to achieve a sense of ownership by all stakeholders, IWRM promotes integration at that appropriate lowest level and subsequent higher levels so that resource management is holistically done.

At the same time that these developments were taking place in the water sector, similar ones were taking place in the agricultural sector. This time, it was to address a food crisis. At the Rio Summit, there were land-related chapters of Agenda 21 intended to address the food crisis. These chapters are: Chapter 10 (Integrated Planning and Management of Land Resources), Chapter 11 (Combating Deforestation), and Chapter 14 (Sustainable Agriculture and Rural Development). The food crisis does not stand in isolation.

It is intertwined with the water crisis in the sense that water use in the agriculture sector, the highest water consumer, can be more productively done to achieve higher crop yields. Currently, with a world population of about 6.5 billion, about 840 million people or 13% of the world population do not have access to sufficient, nutritious and safe food. (See Figure 1 for the breakdown – Diouf, 2003) The food crisis has produced a twin problem of hunger and poverty with 95% of those most vulnerable living in developing countries of which majority are in sub-Saharan Africa.

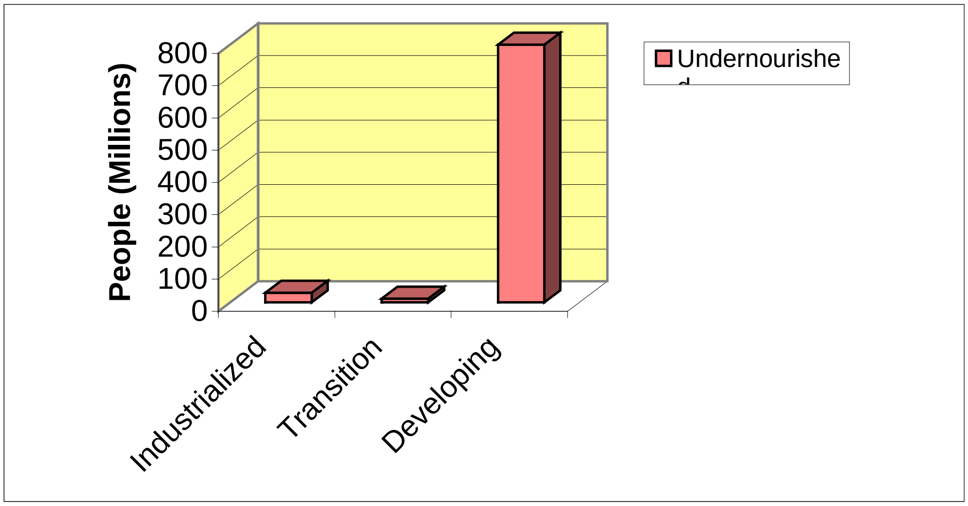

Figure 1: World population without access to sufficient, nutritious and safe food

The mechanism that the United Nations set up to monitor and implement Agenda 21 is the Commission on Sustainable Development (CSD) which holds annual sessions in New York. Of particular interest to the water and agriculture sectors were the sessions CSD-2, CSD-6, and CSD-8 meetings. (The postfix relates to the number of years after the Rio summit of 1992.) These meetings emphasized the need for urgent and reinvigorated actions by governments, civil society, research institutions, bilateral and multilateral donor agencies and NGOs for the implementation of Agenda 21, particularly in achieving participatory approaches, gender mainstreaming, and linking agriculture, land and water in an integrated fashion. It therefore followed naturally that at Rio+10 summit in Johannesburg between 26 August and 4 September 2002, one of the major themes was Water and Food Security. Other than the Rio and Johannesburg summits, there have been other major international fora and conferences where water and food security were the most topical subjects for discussion, and these are the 2nd World Water Forum in The Hague (2000), Millennium Summit of the United Nations in New York (2000), the International Freshwater Conference in Bonn (2001), World Food Summit in Rome (June 10-13, 2002), the 3rd World Water Forum in Kyoto, Osaka and Shiga in Japan (March 16-23 2003), in which were identified the challenges of meeting basic water needs, securing food supply, protecting ecosystems, sharing water resources, managing risks, and prudently managing water. The need to revolutionalise water use in the agriculture sector to increase productivity per unit of water "more crop per drop" was highlighted by the Secretary General of the United Nations, Kofi Annan at the Millennium Summit in 2000. Presenting a report to the Johannesburg summit in 2002, the Prince of Orange called for maintaining the level of diversions of freshwater at the 2000 levels to produce more food needed to feed growing populations. It is this linkage between water resources management and food production that has been lacking in many research projects that have been carried out in research institutions and universities. Underscoring the need for this linkage, the Chair of the Challenge Program Consortium and the Director General of the International Water Management Institute (IWMI), Prof. Frank Rijsberman, at the Johannesburg summit stated, "agricultural research still has a long way to go if we are to provide governments, water managers and farmers with the knowledge and tools they need to solve the water crisis." This linkage is at the heart of this paper.

2 Regional Perspective

It is commonly said that we need to think globally so as to act locally. This is particularly true in a highly globalised world where our experience of time, space, distance and knowledge has taken a radically new meaning. In acting locally, therefore, it must be understood that we are doing so in consonance with global trends. There have been significant reforms in legislation in the water sector in many SADC countries. These reforms have been tailored along the lines of the global trends earlier presented. We briefly present such reforms in three selected countries of SADC.

In Namibia, apart from the Namwater act of 1997 which established the Namibia Water Corporation Limited, a water resources management review was initiated with immediate objectives to examine current water resources management practices; define the issues and evaluate the impact of water resource allocation, water use and waste water disposal practices; and propose policies, institutional arrangements, planning, monitoring and enforcement processes which will:

i) provide for the equitable allocation of water resources,
ii) ensure the environmental sustainability of water use and re-use,
iii) support long-term social and economic development of Namibia,
iv) ensure full participation of the stakeholders, and
v) develop and strengthen capacity of Namibia to manage its scarce water resources.

The South Africa National Water Act of 1998, and similarly the Zimbabwe Water Act of 1998, promoted sustainable, equitable, and efficient allocation and use of water within the framework of integrated water resources management for social and economic development. In carrying out reforms in the water sector, the South African Government followed internationally agreed courses of action, as contained in Agenda 21 and subsequent developments in the water and agriculture sectors. The National Water Resource Strategy (NWRS), that provides the framework for implementing the Act, has just been completed (DWAF, 2004). It identifies the priorities for water use and allocation to the different sectoral uses. The priorities clearly indicate that hard choices await South Africans in the years ahead as sectoral water demands grow with increased population and dwindling freshwater sources coupled with climatic variability, so that the challenge will be establishing a balance between efficient water utilization (with possibility of water re-allocation from low-benefit uses to high-benefit uses) and equitable access for all (particularly historically disadvantaged groups). It is worth noting that the NWRS sees this challenge as a unique period of opportunities for all South Africans, with the former Minister of Water Affairs and Forestry stating, "But water management is not just about solving problems, it is also about creating opportunities." (DWAF, 2002) There is one key modification to the fourth Dublin principle in the reforms that have taken place in most SADC countries, and this has to do with considering water both as a social and economic good. This modification attempts to correct past discriminatory practices that existed when certain segments of society were marginalized and denied access to water and land resources; it is also recognises that water is a commodity essential to human dignity.

3 The needs and challenges

Growth in population is a global trend that is at a rate of less than 1%, but it is of immense concern in developing economies of Africa where the growth rate is about 2.9%. Coupled with this is the growth of cities and urban centres whose populations are likely to outstrip those in rural areas in not too distant future. These developments place enormous pressure on already heavily committed water resources, with expected increases in demands for urban water supply and industrial activities and in the agricultural sector to grow more food to feed more people. One implication of this trend is that water authorities will have little room to manoeuvre but to first meet urban water needs and those of the mining and industrial sectors, which contribute more to the national economy before channelling water to the agricultural sector. Even with the intervention of cost-effective water demand management and conservation strategies, population growth is most likely to prompt water re-allocation from the agriculture sector for the urban and industrial sectors. This is subtly already alluded to in the National Water Resource Strategy (DWAF, 2004). At the same time, agricultural production will be expected to increase to feed more humans with less amount of water to achieve national food security. This is the daunting challenge of the 21st century. Current food insecurity in SADC countries as illustrated in Figure 2 with 12.8 million persons in need of food aid provides an indication of the critical nature of the food crisis.

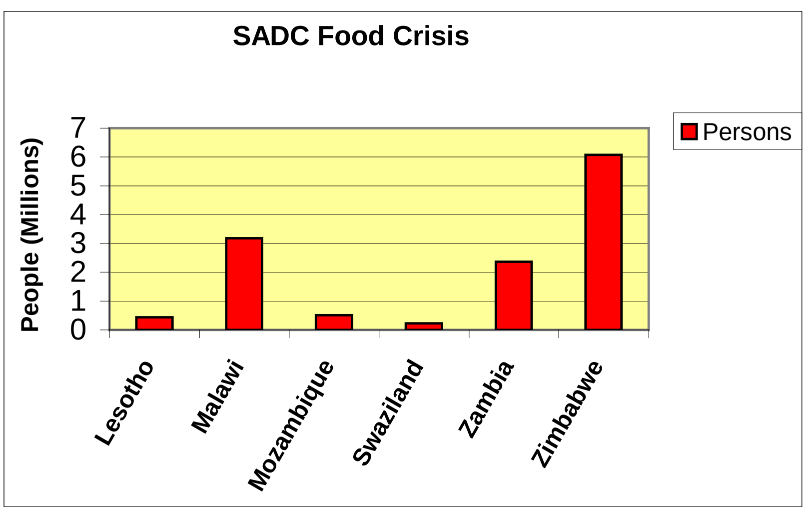

Figure 2: SADC food crisis (SADC, 2003)

The levels of total amount of freshwater diverted for agriculture use are already very high compared to other sectors of national economies. These levels are presented in Figure 3 for some selected countries. It shows that over 80% of the total freshwater diversions go to agriculture in sub-Saharan Africa, which agrees with the international observations that agriculture is by far the world's largest direct water-dependent human activity (Rockstrom, 2003b). With increased demands of freshwater for the urban, industrial and agricultural sectors, efficient and sustainable water resources management will be required to meet the needs of these sectors and at the same time achieve social and economic development.

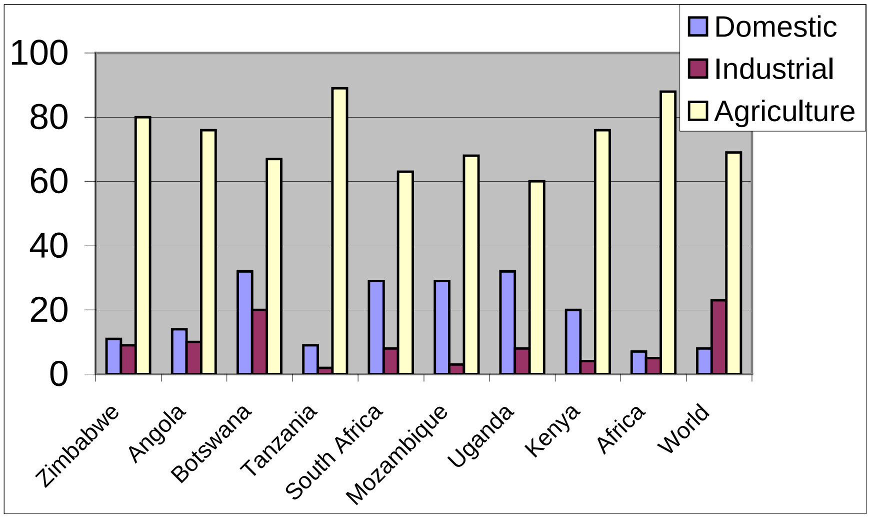

Figure 3: Freshwater diversions to different sectors

Coupled with growth in population, poor land and forest management practices have caused extensive land degradation, loss in ecological resilience, vegetation cover and soil fertility, and siltation of rivers and reservoirs. The pressure on the land from livestock grazing in many farming communities is enormous. Vegetated areas are now bare because most of the trees have been felled for fuel without concerted efforts to replace them. Soil erosion is rife, resulting in heavily silted rivers which flood their banks during the wet months but are completely dry when the rains cease, while productive lands have become deplete of nutrients. Some of the immediate consequences of this environmental degradation are the loss of once fertile lands, resulting in very poor crop yields and loss of income by farmers (reduced livelihoods and standard of living – poverty) and the loss of ecological resilience, thereby increasing the devastation from floods and droughts. Since most of the farmers in sub-Saharan Africa are rural dwellers, the dire level of poverty from poor land and forest management practices has led to demographic displacements of huge proportions. Urban centres are swelling up with young productive men exiting in large numbers from rural areas, so that by 2025 it is expected that over 50% of the worlds population will live in coastal cities (Rockstrom, 2003a; Falkenmark and Rockstrom, 1993). In sub-Saharan Africa, this might occur much earlier because of the larger rate of growth in population. Rockstrom (2003b) sums it all when he mentions that regions facing the largest food needs are subject to four fundamental constraints, which are population growth, poverty, erosion of ecological and social resilience, and climatic change.

Irrigated agriculture was once thought to play a dominant role in alleviating the food crisis in developing economies, but this view, promoted by the West, is being challenged in view of emerging data (Falkenmark, et al, 2001; World Bank, 2001). In sub-Saharan African, overall water use efficiencies are between 20% and 30%. This is wasteful, considering the increased competition for more water by other sectors. Furthermore, the cost of development of irrigation systems in sub-Saharan Africa is more expensive than in developed countries (World Bank, 2001). One implication of this is for farmers in developing countries to resort to growing high value crops or increase production to be able to meet the high investments, but that is difficult to achieve by smallholder farmers who do not have the capital to purchase inputs and embark on grand production improvement objectives.

In contrast to developed countries where a small percentage of the population is involved in agriculture production, farmers in sub-Saharan Africa constitute the largest workforce in the productive sector. Whereas mining, manufacturing, eco-tourism and commercial sectors are considered the more productive sectors in terms of contribution to the GDP, they employ less persons than the agriculture sector. It is for this reason that the agriculture sector is viewed as the engine for overall social and economic growth in sub-Saharan Africa. "The importance of agriculture is proven by the historical development paths of all developed countries or countries like the Asian Tigers that passed the agricultural transition towards industrialization. The few historical exceptions to the rule are the countries in which mineral and oil resources provided the motor of the economy and where agriculture somewhat lagged behind." (van Koppen, 2003). While suggestions have been made for water re-allocation from agriculture sector to more productive sectors, the social implications may well outweigh the economic gains. What is needed the most is more efficient utilisation of irrigation water (Basson et al, 1997).

4 Opportunities

The aforementioned needs and challenges provide vast opportunities for action research that promises to make a positive impact on agricultural production, particularly for smallholder farmers, many of who remain at the level of subsistence farming with very low family incomes. It is now widely recognised that there is a strong relationship between food insecurity, poverty and access to productive water and land. The living standards of poor smallholder farmers can be drastically improved if they are impacted with the skills and tools for managing water, even under rain-fed agriculture, so that their crops receive adequate water from the time of planting to that of harvest. In that way crop failures are minimised, crop yields can be increased with attendant benefits of improved incomes and livelihood.

For (semi) arid regions of SADC, there are now prospects for drought mitigation measures which will greatly reduce risks associated with crop failures that the region has witnessed for the past 2 years. These prospects are as a result of low-cost rainwater harvesting technologies that can be implemented so that when prolonged dry spells occur during the crop development period, harvested water can be used for supplementary irrigation, thereby eliminating physiological damage to the crop due to water stress. Managing this risk of rain-fed agriculture holds the key to achieving food security in the SADC region. Droughts can be classified into four types (UNEP, 2004) as meteorological drought, agricultural drought, hydrological drought and Socio-Economic drought. For convenience we will class them as: absolute drought in which water is insufficient to support biomass production and agriculture drought which is due to diminished water uptake capacity of the plant due to physiological damage inflicted on it during period of water stress. Absolute droughts cannot be managed, but agricultural ones, to which many droughts in the SADC belong, can, with reasonable yields being obtained.

The kind of research that can bring about these opportunities is action-based research in agro-hydrology. Research in agro-hydrology is interdisciplinary as complexities of hydrology, land interactions and flow paths through the landscape are fundamental to the question of human development and use of water resources and have many counterintuitive characteristics, which require careful analysis over spatial and temporal scale (CGIAR, 2002). It provides experts in water resources engineering, agronomy and soil science a forum for sustained interaction and communication through which they get to understand themselves at the fringes of their technical expertise, while at the same time being able to promote their individual expertise to achieve knowledge-base synergies. It is this that makes research in this area not only challenging but quite exciting. By agro-hydrology we mean the integration of water resources management with land and soil fertility management for enhanced crop water productivity (tons/amount of water) at all scales from the farmer's plot to the basin scale. Agro-hydrology is a research field that transcends the traditional fields of agronomy, irrigation engineering, and hydrology to the integration of water resources management, crop water productivity, soil fertility and land management at all scales in the hydrophysical system. Such broad based, multidisciplinary and detailed research is required to quantify ecosystem services, define and quantify impacts of agricultural development and management on them, and understand trade-offs so that appropriate solutions are offered to the policy makers and users (CGIAR, 2002).

It is worth mentioning that the level of funding for research in agro-hydrology or water resources management in agriculture is very high. Without indicating the amounts, many research-funding agencies have identified this area as one of their key strategic areas for the next five years. This allows for human capacity building in the education sector with the training of students for Masters and Ph.D degrees, and in the farming sector with the development of farmer field training materials. Education, training, research, and development are the keys for framing the long-term potential, capacity building and pursuing the effective efforts in the planning, development and management processes (Gupta, 2001) needed in agro-hydrology.

5 Water Resources Management

The management of water in agriculture can be examined at four scales, namely crop, field, catchment, and basin scales. The issues of interest differ from one scale to another, with their complexity increasing as we move from the field to the basin.

5.1 At crop scale

At the crop scale, the crop or plant interacts with the hydrologic (energy) and nutrient cycles. Precipitation is the only random variable that is outside human control. The other variables, such as transpiration, runoff, and percolation depend on the stage of the crop development, ground surface conditions and soil moisture. To optimise the use of the available water to the crop, there should be adequate amount of water in the root zone for uptake by the crop for food production through the process of photosynthesis, and the release of vapour by transpiration through the leaves. It can be shown that there is positive correlation between soil moisture and plant transpiration and as well as crop yield, and it is for this reason that the amount of water transpired is commonly referred as productive water. This is in contrast to the water that is lost through evaporation from the ground surface, which does not contribute to the yield of the crop, and as such referred as unproductive water. As such, deep percolation also does not contribute to the plant development, but to groundwater that may flow to an adjoining stream with which the aquifer is in hydraulic contact. The amount of runoff depends on the ground surface conditions. Rockstrom (2003b) proposes the vapour shift concept for improving water productivity.

This can be done by reducing bio-physical deficiencies, (hydro-climatic deficiency, soil deficiency and plant deficiency), by maximising agro-hydrological factors such as water availability (by maximising rainfall infiltration and soil water-holding capacity) and crop water uptake capacity (by maximising canopy cover, root density and root depth). A similar concept is also advocated by Wallace and Batchelor (1997). Implementation of these concepts requires meaningful research that will detail their effects on a bigger scale.

5.2 At Field Scale

On the field, a water balance analysis is carried out to assess water use efficiency and crop productivity. A similar analysis is usually carried out by the agronomist to evaluate nutrient balance. There is ample evidence to indicate that crop yields increase exponentially with water productivity or plant transpiration (Pandey et al, 2000; Rockstrom et al, 1998). Figure 4, indicative of this trend, is adapted from Rockstrom (2003a) which was obtained from water balance analysis on pearl millet in Niger. At the field level, such water balance analysis when carried out in conjunction with soil fertility management provides valuable information on how to optimise crop water productivity and thereby yields.

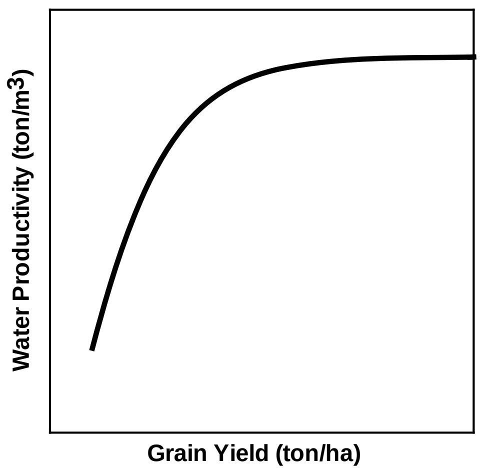

Figure 4: Typical crop water productivity ***(Adapted from Rockstrom, 2003a)***

Under rain-fed agriculture, rainwater harvesting (RWH) serves as a risk mitigation measure. RWH is a controlled interception of storm runoff and its subsequent storage for productive uses (cropping, livestock, domestic use, etc). RWH systems include in-situ water conservation (conservation tillage and soil moisture enhancement practices – mulching, ridging, use of organic fertilizer (manure), etc) and runoff interception methods with surface and subsurface storage facilities (Ngini, 2003). There is a wide scope for investigating different RWH systems and identifying the one or combinations most appropriate for a particular field. This kind of investigation has great prospects in reducing risks associated with rain-fed agriculture which is engaged in by majority of peasant farmers. Of interest, especially in the South African context, is that the National Water Act grants the Minister the right to specify and prohibit stream-flow reducing activities and at the same time require water use permit for any type of waterworks, of which RWH systems could be one if applied at an increasingly large scale. This therefore has implications on the applicability of RWH and other drainage modifying activities and research on the same could also pave a way for policy change that will be beneficial or, at least, allow some trade-off at the catchment and basin scales.

As stated earlier, there is a distinction between absolute drought and agricultural drought. Absolute drought is when cumulative rainfall during cropping season cannot support biomass production (< 300mm/year); it cannot be managed. Agricultural drought is when crops are water stressed due to lack of soil moisture in the root zone, giving rise to physiological damage of plant and reduced root water uptake capacity. Any prolonged dry spell of 1-2 weeks during crop growth and development can lead to agricultural drought and crop failure. During this period, harvested rainwater can be used for supplementary irrigation. Using the daily rainfall data for Bulawayo for the 2002/2003 presented in Figure 5, we observe that bridging the dry spell period with supplementary irrigation would have saved crops from the failures experienced. What supplementary irrigation does is similar to the half-month moving average of the daily rainfall data indicated in Figure 5 that is devoid of dry spells. Nature could not provide this trend but expects that we bring it about.

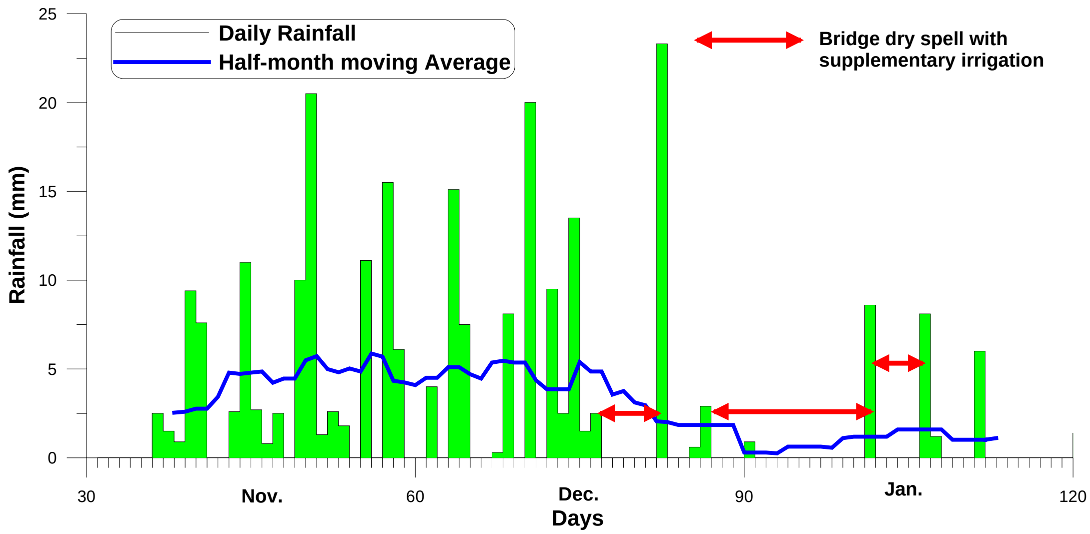

Figure 5: 2002/2003 daily rainfall for Bulawayo analysed for drought mitigation

Under irrigation at the field scale, water use efficiency and soil fertility studies can be carried out to identify the most efficient irrigation system that optimises crop yield. Crop-targeted water application systems like drip systems which enhance soil moisture in the root zone, thereby enhancing plant transpiration, can be examined. Other measures that could be examined on the farmer field are water conservation measures, which reduce soil evaporation and deep percolation but attempt to increase plant transpiration; supplemental versus full irrigation, analysis of costs and benefits of using water now and foregoing it later (CGIAR, 2002). Field studies designed to increase irrigation efficiencies are of paramount importance in view of the large amount of freshwater diversions to this sector with only about 25-30% of diverted water being utilised by plants under convectional gravity systems (Rodda, 2001). Increased competition for water from other sectors might place agriculture to become a residual user of water with attendant implications on food security (CGIAR, 2002). It is these studies that hold the key to avoiding policy decisions on water re-allocation from the agriculture sector with dire social consequences.

5.3 At Catchment scale

At the catchment scale, the issues that are examined are somewhat different from the other scales. It is at this scale that the benefits of integration in water resources management can be most derived. Of paramount importance is the bridging of the conceptual gap in relationships between land productivity and hydrology (Oyebande, 2001). This calls for addressing a number of related issues such as changing the paradigm shift from land productivity to water productivity both in the field and in research and development areas (Oyebande, 2001). Within a catchment, there are different farms with different farming systems and different water usage levels. Taking the case of the Mzingwane catchment of the Limpopo basin as an example (Figure 6) from the research project on "The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods in the Water Scarce Limpopo Basin", we observe that there are about six farming systems being practiced – subsistence/communal, livestock, mixed, wildlife/ranching/tourism, commercial, and horticulture. These different farming systems have different water requirements, which have to be properly accounted for in the overall water requirement for the catchment.

There are also different water users. For instance, water is transferred out of the catchment to Bulawayo, the second largest city in Zimbabwe, from the Upper and Lower Ncema, Insiza, Inyankuni, and Mzingwane dams for domestic, commercial, and industrial purposes. A stakeholder analysis is required to identify the primary and secondary stakeholders in the catchment.

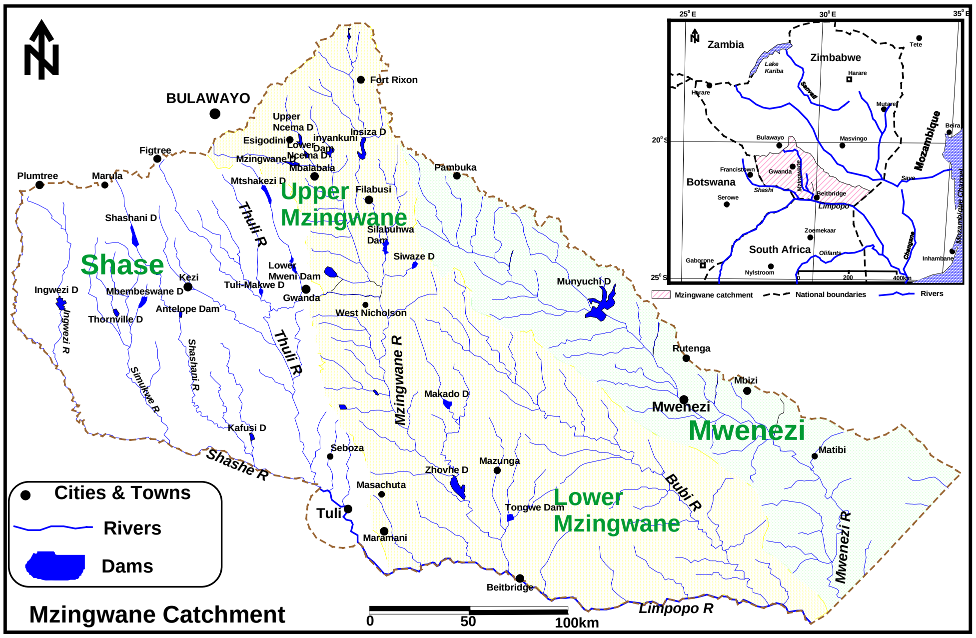

Figure 6: Mzingwane catchment of the Limpopo basin

It is also important to evaluate the upstream-downstream interactions. Upstream water users in a catchment have the advantage of having more access to flows and good quality water than downstream users who have to contend with more saline return flows from those upstream. In managing water resources at the catchment scale, there is the need to have catchment managing institutions who understand the dynamics of upstream and downstream user interactions and are able to promote sustainable use of water resources that takes into account multisectoral use, including, not the least, environmental flow requirements. It is with this understanding that water rights can be allocated to different water users from whom responsible use will be expected.

A significant pricing shift is required in the agriculture sector if the benefits of water resources management are to be realized. This is a policy issue. Incentives for conserving water that are already in place or being promoted for urban and industrial sectors need to be extended to the agriculture sector so that farmers can be encouraged to conserve water on the field. Currently, the water pricing policies in the agriculture sector are on the basis of cropped area rather than actual volumetric water used by the farmer (Figure 7). This has to change to encourage farmers to use less water with improved water-saving irrigation systems like drip irrigation or other crop-targeted irrigation systems. When such a policy shift takes place, there is every reason to believe that farmers will begin to seek water-saving irrigation systems in order to cut down on their water bills. There will be considerable infrastructure adjustments that will be needed in farming fields to accompany this policy shift. In our opinion, there is some urgency for this policy shift to be effected now rather than in the future when the current water crisis might have attained an unprecedented level. Ultimately, water efficiencies should be calculated and optimised not only in physical terms, but also in economic, social, and environmental terms (Wallace and Batchelor, 1997). It is needless to say that research provides the interface between ideas and implementation, and hence is a necessary gateway for foreseeing and understanding the possible effects of such proposals.

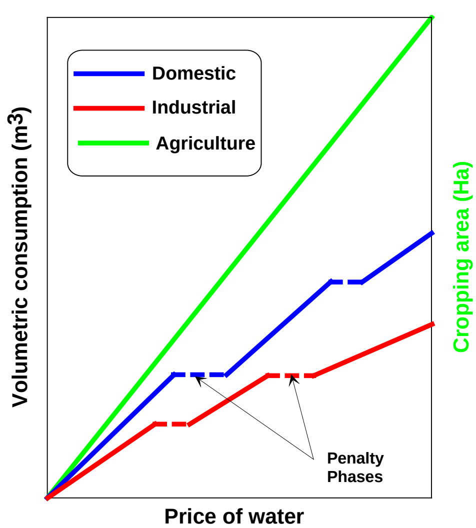

Figure 7: Typical water pricing policies in the urban, industrial and agriculture sectors

5.4 At Basin Scale

At the basin scale, the issues of interest are similar to those at the catchment, except that they are more complicated. Integration in water resources management has to be carried out at a higher dimension. The issues become more complex when the catchments are in different national boundaries, in which case the States that share the water resource have to be well represented in an institution (River Basin Organisation) which takes decisions on the allocation of the resource on the basis of clearly defined and agreed objectives. The Helsinki Rules on the uses of the Waters of International Rivers adopted in 1966, and the United Nations Convention on the Law of Non-navigational Uses of International Watercourses (UN, 1997) , and SADC Revised Protocol on Shared Watercourses (SADC, 1998) provide useful guidelines for the equitable allocation of water in shared watercourses to the basin States, including maintaining ecosystem functions in the different catchments. What is most crucial in an efficiently operating River Basin Organisation (RBO) is adequate human capacity in the basin states. When the playing field is not levelled, some basin states might tend to dominate the decision-making process, and that could make the other states not to take ownership of the process. In a situation where the states that are left out of the decision-making process are upstream, they could stand in the way of sustainable use of the water resource. It is for this reason that resources should be made available to build capacity in the water-related institutions in the basin states so that all states are adequately represented to make useful contribution to the activities of the RBO.

6 Concluding Remarks

This paper has highlighted some of the challenges in the water and agriculture sectors that are being experienced by growing populations, particularly in semi-arid regions, and the prospects presented by action research in agro-hydrology with monumental benefits of increased food production and increased farmer incomes. With the large number of rural folks involved in rain-fed agriculture, research projects like the one titled “The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods in the Water Scarce Limpopo Basin,” being funded by CGIAR, offers great hope to rural farmers in mitigating against risks associated with droughts in semi-arid environment. Water re-allocation from irrigated agriculture to urban and industrial sectors is inevitable in the future, and it is unlikely to attract undesirable social consequences of unemployment in the agriculture sector if the water being re-allocated is that saved through sustainable and efficient use of water in agriculture. New water conservation technologies such as rainwater harvesting offer the hope that optimal use of water for agriculture will reduce the threat of food crisis. Appropriate policies, including on water pricing, are needed to provide a framework for that will support the new era of sustainable water resources management in the agriculture sector.

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References

Basson, M.S., van Niekerk, P.H. and van Rooyen, J.A. (1997) Overview of water resources availability and utilisation in South Africa, Department of Water Affairs & Forestry Report PRSA/00/0197, 71pp.

CGIAR (2002) Challenge Program on Water and Food, Background Paper 4

DWAF (Department of Water Affairs and Forestry) (2002), Republic of South Africa Draft National Water Resource Strategy, Proposed first edition: Summary, Department of Water Affairs & Forestry, 37pp.

DWAF (2004), Republic of South Africa National Water Resource Strategy

DFID (1998) Guidance manual on Water Supply and Sanitation programmes, Department of International Development, London, UK.

Diouf, J. (2003) What is Food Security, presented at the 29th session of the committee on World Food Security, FAO, Rome.

Falkenmark, M. and Rockstrom, J. (1993) Curbing rural exodus from tropical drylands, Ambio 22(7), 427-437.

Falkenmark, M., Rockstrom, J. and Savenije, H.H.G. (2001) Feeding eight billion people: Time to get out of past misconceptions, Stockholm Water Front, April edition, 7-10.

Gupta, A D (2001), Challenges and opportunities for water resources management in Southeast Asia, Hydr. Sci. Journal, 46, 6, 923-935

GWP (2000). TAC Background Paper No 4: Integrated Water Resources Management

Ngigi, S.N. (2003) What is the limit of up-scaling rainwater harvesting in a river basin? Phys. and Chem. of the Earth, 28, 943-956.

Oyebande, L. (2001), Water problems in Africa – How can the sciences help? Hydr. Sci. Journal, 46, 6, 947-962.

Pandey, C.L., Maraville, J.W. and Admou, A. (2000) Deficit irrigation and nitrogen effects on maize in Sahelian environment, I. Grain yield and yield components, Agric. Water Management, 46, 1-13.

Rockstrom, J. (2003a) Resilience building and water demand management for drought mitigation, Phys. and Chem. of the Earth, 28, 869-877.

Rockstrom, J. (2003b) Water for food and nature in drought prone tropics: vapour shift in rain-fed agriculture, Phil. Trans. R. Soc. Lond. B, 358, 1997 – 2009.

Rodder, J. C. (2001) Water under pressure, Hydr. Sci. Journal, 46, 6, 841-854.

SADC (Southern African Development Community) (1998) Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC) Region.

SADC (Southern African Development Community) (2003) SADC fights to eliminate the food crisis, http://www.sadc.int/fanr, Directorate of Food, Agriculture and Natural Resources.

UN (United Nations) (1997) Convention on the Law of the Non-navigational Uses of International Watercourse, Adopted by the UN General Assembly in resolution 51/229 of 21 May 1997.

UNEP (2004), Environmental Emergencies News, Issue 2, February 2004.

van Koppen, B. (2003) Water reform in sub-Saharan Africa: what is the difference? Phys. and Chem. of the Earth, 28, 1047-1053.

Wallace, J.S., Batchelor C.H. (1997) Managing water resources for crop production, Phil. Trans. R. Soc. Lond. B, 352, 937 – 947.

World Bank (2001) Water for food strategy for sub-Saharan Africa, Draft Review Proposal.